

## 2.0 EXECUTIVE SUMMARY

This document presents the results of a safety evaluation of a commercial payload processing facility owned and operated by Astrotech in Titusville, Florida. The evaluation was performed by a team of experts from the Office of Commercial Space Transportation (OCST) and the Environmental Protection Agency (EPA). Under the Commercial Space Launch Act of 1984, as amended (Public Law 98-575, 100-657), the U.S. Department of Transportation (DOT) is responsible for licensing and regulating U.S. commercial space launch activities in a manner that protects public safety, safety of property, and U.S. national security and foreign policy interests, and encourages development of a viable domestic commercial launch industry. When questions arose concerning the safety of Astrotech's activities, the Lieutenant Governor of Florida requested OCST to conduct an impartial and focused review of the payload processing facility and operations. Because activities at Astrotech could affect safety of licensed launch operations, OCST agreed to undertake the safety evaluation.

The approach used in the evaluation was first to identify the major concerns of the state and local regulatory, planning and emergency preparedness officials, Astrotech, and the community. These concerns focused on the operations, procedures and policies in place at Astrotech to protect public health and safety and the environment. Issues included building safety design and siting, operating policies and controls, safety systems, training, and emergency preparedness and planning.

The next step was to visit Astrotech to gather specific information concerning the buildings, operations and equipment, hazardous materials handled on-site, safety systems and equipment, and emergency preparedness and planning. The visit allowed the evaluation team to see the safety and control systems; view some hazardous processing operations; interview key Astrotech safety personnel; review relevant documents, design drawings, and permits; and interview local emergency response and planning officials.

After the data gathering phase, the team analyzed the information, evaluated safety systems, performed hazards analyses, and identified potential risks to the public posed by credible accident scenarios that result in worst case releases at the facility. The final step was to make recommendations for changes or additions to procedures, policies, equipment, or facility design that could help prevent future problems or mitigate anticipated impacts on public health and safety of possible accident scenarios; in addition, the evaluation team prepared guidance to assist in evaluating other industrial facilities where public health and safety concerns may arise.

This report presents the findings and recommendations of the

safety evaluation team, with emphasis on public health and safety risks that could arise from operations at the Astrotech facility. The team did not perform a transportation risk assessment; nor did the team evaluate issues of worker safety, either during routine operations or during accidents.

## **Site Overview**

Astrotech is a commercial payload processing facility located in an industrial park in the city of Titusville, Florida. The site is about 3 miles from the Kennedy Space Center (KSC) and is near an airport, offices, a manufacturing plant and a residential housing development. The site covers approximately 37 acres and is divided into hazardous and non-hazardous work areas. Operations are conducted in the work area appropriate for the nature of the materials involved.

There are six buildings on the site. Buildings 2 and 3 are in the hazardous area and house the operations that involve the handling, storage, and transfer of solid rocket propellant, liquid rocket propellant and explosive material. (Note: no liquid propellants are allowed in Building 3.) The remaining buildings (1, 1A, 4, and 5) are in the non-hazardous work area. They contain space for offices and administrative activities as well as for storage of support equipment, and for functional testing, leak checking, and assembly of spacecraft prior to hazardous operations. Hazardous operations involve handling of solid rocket motors; transport, transfer and loading of liquid propellants; and lifting, spin balancing and transporting of fueled spacecraft to a launch pad at KSC or Cape Canaveral Air Force Station (CCAFS). Operations are carefully scheduled between the hazardous and non-hazardous work areas to minimize risks to processing personnel and sensitive spacecraft equipment and to maximize efficient processing flow.

Since Astrotech is located in an industrial park, there is some separation between the site and residential areas. However, concerns regarding accidents and potential impacts on nearby populations have focused public attention on the facility and its operations.

## **Facility Features**

Astrotech provides a specialized facility and limited facility support under contract to payload customers who perform the final assembly, inspection and processing of their payloads prior to launch. The activities involved in preparing a payload for flight typically include assembly, leak testing of propellant systems, installation of other equipment, functional testing, cleaning, propellant loading, pressurization of tanks, spin balancing (if required), and mating the satellite with assist motors. These operations require special "clean room" conditions (with specific limits on the amounts of dust and particles in the

air) and stringent controls on hazardous activities. Astrotech is one of the newest payload processing facilities in the U.S. and the only fully integrated one owned and operated by a commercial entity. Thus, Astrotech has taken advantage of the experience and knowledge gained by the National Aeronautics and Space Administration (NASA) and the Air Force over the last three decades of space launch activities to build and operate a state-of-the-art payload processing facility.

Since Astrotech is a commercial concern it is subject to federal, state and local regulatory requirements concerning such things as fire and building safety, worker safety, emergency response and preparedness planning, waste handling and disposal, transportation of hazardous materials, environmental emissions, and notification of accidental releases. The safety evaluation team found that Astrotech complied with all applicable safety, environmental, and emergency preparedness regulatory requirements.

The buildings in the hazardous work area of the facility were designed, sited and constructed to meet Department of Defense (DoD) and Bureau of Alcohol, Tobacco, and Firearms (ATF) explosives safety standards because solid and liquid rocket propellants and explosive materials (e.g., ignition and separation devices) are routinely handled, transferred, and installed during payload processing operations.

Building 3 is used for the long- and short-term storage of payloads, solid rocket motors (containing solid propellant classified by DoD as mass-fire) and any other ordnance-containing flight hardware, and other environmentally sensitive flight hardware, as required. No liquid propellants are handled or stored in Building 3.

Building 2 is used for performing operations considered to be hazardous, including loading and transfer of solid and liquid propellant, and is designed to be a total containment facility to prevent the release of propellant vapor or liquid into the environment from a small release during normal operations. The building can effectively be sealed to trap propellant vapors inside until treated. In constructing one of the newest facilities of its kind, Astrotech was able not only to incorporate lessons learned from the years of operation at NASA and DoD facilities, but also to identify the best technologies available, some of which had been developed for use in other industries or applications, and to transfer and apply these technologies to improve payload processing operations safety.

The special features and systems that were incorporated by Astrotech and that the safety evaluation team found to be an improvement over older processing facilities are briefly described below.

#### Vapor Containment

Building 2 was designed and built to contain a propellant leak or spill, should one occur inside during normal operations. The only exhaust from the building is through a scrubber that treats any propellant vapors generated as part of the fuel/oxidizer containment and neutralization system (see below). Also, a recirculation fan is installed inside Building 2 for agitation of air and to aid in diluting and breaking down of propellant vapor in the event of a major spill in the building.

#### Electrostatic Dissipation

The floor in the high bays and North Airlock in Building 2, where hazardous processing operations are performed, is covered with vinyl tiles, impregnated with graphite and bonded to the concrete with conductive mastic. This dissipates static electricity to the building grounding grids, reducing the threat of electrostatic discharge that might ignite SRMs or flammable liquid propellants. This technology was originally developed for use in hospital operating rooms where static electricity created severe potential safety hazards in dealing with sensitive instruments.

#### Spill Collection and Containment

Propellant loading operations are conducted on "fueling islands," which are in the center of a work area and are surrounded by a stainless steel collection trench that slopes underground and drains to the containment and neutralization tanks outside the building (described below). If a spill occurs, it is directed into the trench drainage system, confining the spill and making cleanup easier. In the event of a fuel spill involving a fire, the trench system would also serve to confine the fire to the fueling island and help prevent its spread to other areas.

#### Fuel/Oxidizer Containment and Neutralization

There is a containment system, consisting of oxidizer and fuel holding tanks, separated by appropriate valving and manually-switched piping connected to a vapor scrubber. The scrubber is operated under a permit from the Florida Department of Environmental Regulation (DER) for anhydrous hydrazine, monomethyl hydrazine and nitrogen oxides. Following a complete processing operation, the contents of the tanks are neutralized, and after testing by the city, are discharged to the city of Titusville sewer.

#### Remote Visual Access To Hazardous Operations

Since Astrotech monitors all hazardous operations that are performed by its payload customers, explosion-proof observation windows were installed between the control rooms and bays in Building 2 to reduce the number of personnel in the bay during propellant sampling and loading. This allows safety and quality control personnel required to observe and monitor hazardous operations to do so without being physically present in the bay.

#### Pre-Action Suppression System

A computer-controlled fire suppression system was installed that has compressed air in the lines, maintaining a "dry pipe" condition. Activation of this pre-action system requires two independent events: first, smoke/heat detection alarm signal from any of the detectors mounted in the bays, airlocks, or the heating, ventilating and air conditioning (HVAC) system or from a manual pull station; and second, sufficient heat to melt the fusible link in the sprinkler head. The first opens a valve releasing the water to the sprinkler system; the second releases the water from the sprinkler head to wet the area. This system design provides some special protection for sensitive payloads and other equipment in case there is a false alarm or other problem.

#### Computer Monitoring of Alarms

Alarms are automatically sent to the guard house at the front gate via computer link for various parameters and systems including: temperature and humidity (HVAC system), loss of air pressure in the pre-action fire suppression system, toxic vapor detector alarm, toxic vapor detector status problem such as low battery or a tape break, generator failure, and an automatic or manual fire alarm. The alarm panel indications displayed to the guard allow prompt identification of potential problems and notification of appropriate personnel.

#### Vapor Detectors

Astrotech monitors atmospheric conditions in Building 2 using state-of-the-art portable toxic vapor detectors to supplement the more conventional vapor analysis techniques used (Draeger tubes). Vapor monitoring is done at all times that liquid propellant is in the building. These detectors are extremely sensitive and are microprocessor-controlled for speed, accuracy and specificity. The detectors are encased in special explosion-proof clear plastic boxes for use in flammable/potentially explosive atmospheres.

## **Safety Policies and Requirements**

Astrotech has strict safety policies and operating procedures for the use of its facility and support equipment by its payload customers. Because of the high value of their satellites, Astrotech's payload customers also have stringent internal safety requirements. So there is to some extent a system of safety redundancy and crosschecks between Astrotech and its payload customer, with each having considerable interest in ensuring safe and efficient processing operations.

Payload customers are required to provide detailed technical data and operating procedures for all hazardous operations. Astrotech reviews and approves these procedures prior to initiation of operations. Additional Astrotech safety requirements include such things as training and certification of propellant handling teams, scheduling and coordinating all hazardous operations through Astrotech, and safety monitoring by Astrotech and customer safety and quality control personnel of all hazardous operations scheduled for a specific payload.

Astrotech's safety requirements are detailed in two operating documents, Safety Policy and Safety Standard Operating Procedures, which identify what is required of the payload customer by Astrotech in terms of information concerning support equipment (e.g., pressure systems, electrical systems, tanks and lines); certification standards; operating procedures and safety requirements for performing hazardous operations (e.g., ordnance checkout and installation, propellant loading); baseline weather conditions for conducting operations; requirements for lifting and transporting spacecraft; and accident reporting.

## **Emergency Preparedness and Planning**

Astrotech has a written emergency plan that addresses emergency response procedures for incidents that may occur either at the facility or while transporting liquid propellant from and returning any excess to the storage facilities at KSC and CCAFS. The plan was updated in 1988 and is considered an adequate document for dealing with emergencies that could occur. Since it began operations in 1984, Astrotech has never had a release in which reporting to or alerting of emergency response agencies has been necessary.

Astrotech has worked closely with local, county and state emergency response and planning officials in familiarizing them with the facility, its safety systems, the types of operations that are performed, the materials that are handled and their hazards, and the personal protective equipment necessary for personnel responding to emergency situations. The public safety officials interviewed by the evaluation team gave Astrotech high marks for their efforts in these areas.

## **Hazards Analyses and Risk Assessment**

The overall goal of this evaluation was to identify potential risks to the public from accidents that could occur at Astrotech. The hazards analyses were performed by reviewing the facility design, operations and procedures and then defining possible accident scenarios that could produce a hazard to the public. In this evaluation, a scenario leading to a fire and explosion in Building 2 was the baseline for defining accident scenarios that could potentially affect the public. For each accident scenario that could produce impacts on the public an estimate of the probability of its occurrence was made and the potential consequences described. For each potentially hazardous condition, those facility design features and operating procedures that could mitigate the hazard and reduce the associated risk were also considered in making the probability estimates. Any residual risk to the public was then identified.

In performing this assessment, the evaluation team determined credible accident scenarios, regardless of how unlikely, which could result in the largest potential negative impact on the public. If these scenarios produce no significant negative impacts on public health and safety, any lesser accident can also be assumed to have no negative impacts. Hazards analyses and risk assessments require assumptions and data inputs to models which attempt to predict the results of physical phenomena like fires, explosions and the release and dispersion of toxic gases in the atmosphere. The evaluation team made "conservative" assumptions and used conservative or worst case data inputs for these analyses. This means that the assumptions and data inputs err on the side of protecting public health and safety. Therefore, the actual impacts, if an accident were to occur, would likely be considerably less than those predicted.

The results of the analyses indicated that a worst case release is caused by a fire and explosion involving the maximum quantities of liquid propellant permitted on site (2,500 pounds of fuel; 5,000 pounds of oxidizer) and the maximum amount of solid propellant on site (24,600 pounds from the explosive safety siting analyses), that damage or destroy the walls and/or ceiling in Building 2. Gases not consumed in the fire and explosion could then disperse and diffuse in the direction of the prevailing winds.

The probability that any of the identified credible accident scenarios will occur and result in the worst case release is remote (about  $2 \times 10^{-4}$ ), on the order of two such accidents per 10,000 complete payload processing operations. At an average processing rate of ten payloads per year, the probable frequency of such an accident is approximately once in 500 years. In Government payload processing facilities, with many years of combined operating experience, accident scenarios of the severity analyzed in this evaluation have never occurred. So, the safety evaluation team conservatively estimates that even applying an uncertainty factor, the maximum frequency of the worst case release would be once every 100 years.

The consequences associated with these accidents are extremely difficult to predict since there are no mathematical models that take into account fire and explosion inside a building, followed by damage to the building allowing release of toxic gases. Thus, conservative estimates for the amount of propellants involved in the initial accident were made. Also, conservative assumptions were made based on actual accident experience, regarding the amounts of propellant that would be available to be released (i.e., not consumed in the fire and explosion). Typical ambient temperature and humidity were assumed, along with conservative wind conditions. These estimates resulted in very conservative (protective) estimates of the concentrations of toxic gases that could result in the nearby atmosphere.

Accident consequences, including ground level concentrations of toxic gases and overpressure effects of explosions, were examined to estimate any risk to the public. The analyses indicated that no explosion effects, including primary overpressure effects and secondary effects such as glass breakage and flying debris, would occur beyond the facility boundary.

To quantify the hazard from toxic gases, it is important to use a standard measurement for airborne toxic hazards. The Immediately Dangerous to Life and Health (IDLH) concentration set by the Occupational Safety and Health Administration/National Institute of Occupational Safety and Health (OSHA/NIOSH) was selected for this analysis. An IDLH, set at a specific value for a particular chemical, is the maximum concentration that one could inhale for thirty minutes, and still not experience escape-impairing symptoms or irreversible injury. Thus, both exposure concentration and duration are important considerations in evaluating effects. EPA uses the IDLH as a basis for performing hazards analysis for community planning, but in order to be protective of the general population has defined a "Level of Concern" (LOC) for a chemical as 10% of its IDLH.

The safety evaluation team compared the predicted ground level concentrations of all resulting toxic vapors (hydrazine; nitric acid, from dissociation and reaction of oxidizer; and hydrochloric acid, from the burning of a solid rocket motor [SRM]) to their IDLH values. The hydrazine concentration outside the facility boundary is never predicted to be above the 10% IDLH level. Nitric acid and hydrogen chloride concentrations outside the facility boundary are never predicted to be above the 50% IDLH levels, and their concentrations will diffuse to below the 10% IDLH levels within approximately 860 feet and 1,225 feet of downwind travel, respectively. At all locations outside the facility boundary, even with a conservative assumption of low wind speed, the exposure duration would be less than a minute. There would be no adverse impacts on the public from exposures at these concentrations for such brief durations.

Thus, a worst case release, which has only a remote

possibility of occurring at the facility, would have no adverse impacts on public health and safety.

## **Findings**

Overall Astrotech appears to have taken every reasonable precaution in designing and constructing a facility which is safe for those living and working nearby and in implementing the policies and operating procedures that have been successfully used by DoD and NASA for many years. The owners commissioned several safety studies, both to site the buildings on the property initially and before design and construction changes for modifications were approved. Astrotech has also tried to identify and incorporate effective safety, monitoring, and detection features into the facility.

### Findings Regarding the Buildings and Operating Procedures

The buildings where hazardous materials are handled are separated from the public and from the non-hazardous work areas by distances determined using DoD and ATF explosives siting criteria.

The buildings and equipment are state-of-the-art design and quality.

Building 2 is designed and operated to minimize the risk to the public from any potential releases of propellant vapor or liquid that could result from a spill occurring inside the building. The containment and scrubber systems provide protection to the public from any incidental exposures during routine operations.

The physical facility and equipment compare favorably with Government facilities that serve similar functions.

Prior to and during operations, policies and procedures are in place to ensure safety. These include attention to all aspects of operations, equipment maintenance and certification, personnel training, and safety systems.

The formal, documented procedures for processing payloads meet all accepted standards as applied by industry, DoD and NASA.

No reportable accidents or incidents have occurred at Astrotech since it began operations in 1984.

Astrotech has continued to update equipment and is committed to minimizing the generation of hazardous waste, as evidenced by the recently ordered closed-loop still for processing and recycling contaminated freon.

## Findings Regarding Emergency Response and Preparedness

Astrotech has an adequate written emergency response plan.

Astrotech has been cooperative and interactive with local and county emergency response and preparedness officials.

Procedures and equipment are in place to protect workers in hazardous situations, to assemble the facility emergency response team should it be necessary, and to call for off-site assistance as required.

## Results of Hazards Analyses

If an explosion were to occur in Buildings 2 or 3, the public would not be exposed to any primary explosion effects from overpressure, flying fragments, or fire.

The worst case accident scenarios, which involve a fire and explosion in Building 2, result in no adverse impacts on public health and safety.

## **Recommendations**

In this section, the evaluation team outlines areas needing additional evaluation and attention by Astrotech to further enhance the safety of its facility and operations. These recommendations can be generally divided into those directed at the systems, equipment, and operations; those dealing with policies and procedures; and those dealing specifically with emergency preparedness and planning:

### Systems, Equipment, and Operations

Evaluate the feasibility and safety of modifying the sequence of processing operations dealing with loading liquid propellants, lifting and mating the satellite with the SRM, pressurizing tanks, and spin balancing operations so that the operations sequence minimizes the chance of a worst case release.

Provide additional communication capability for cart storage rooms (e.g., telephones or direct connection to the guard house).

### Policies and Procedures

Include operational sequencing limitations for propellant loading in the Safety Standard Operating Procedure (SOP).

Develop written guidelines for necessary activities following an "uncontrollable" spill including a definition of incident(s) that initiate an uncontrollable spill, activities that need to be done to mitigate and evacuate the area, and the steps and requirements for re-entry.

Specify with more detail the criteria considered for proper training and certification of customer personnel.

#### Emergency Preparedness and Planning

Provide additional clarification of personnel assignments, especially regarding an assigned back-up to the Safety Officer.

Expand the emergency contacts list to include critical contacts beyond the 911 system (e.g., the county emergency management director), and the phone numbers and contact person for the nearest industrial neighbors.

Add the Superfund Amendments and Reauthorization Act (SARA) Title III reporting requirements for information to be furnished in the event of a release to the plans and procedures.

Perform a simulated exercise of the emergency response plan with emergency responders, even if only a table-top exercise.

#### **Guidelines**

The safety evaluation team found that in the process of evaluating the Astrotech facility, there were generic guidelines that could be outlined in order to assist communities and local response and planning authorities in evaluating the overall safety of industrial facilities. It must be noted that these guidelines are not aimed at the Astrotech facility itself; in fact, in many of the areas identified, Astrotech can provide a model for proper implementation.

It is helpful to coordinate early in the design process with local planning officials, recognized safety experts, and other facilities with similar functions, so that the original construction can incorporate as many safety features as possible. For example, because the Astrotech facility is sited to meet explosive safety distance siting criteria, the public is protected from the primary effects of explosions.

A comprehensive safety program should include operating and maintenance controls, training, documentation and record keeping, and internal audits and inspections. Because the safety program

is a key factor in protecting the public and the environment, the community may want to consider establishing a monitoring program, where an external expert regularly inspects a facility and observes operations to ensure that all aspects of the safety program are implemented.

Along with community emergency planning officials, it is important for facilities to establish an emergency response plan. In order to increase the effectiveness of such a plan, the community and facility should work together to identify facility hazards, determine likely accident scenarios, implement procedures that minimize the likelihood and severity of such accidents, and finally plan how to respond in the event of an accident. Because hazardous materials are necessary for many aspects of industrial processes, it is important that facilities and communities work together to prevent or minimize accidents.

